BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a system and a method for handling the laser-communication multiplexing in chaotic secure communications, and more particularly, for decoding multiplex chaotic laser signals by utilizing a low-pass filter to increase the fractal dimension of the chaotic system, so that the decoding of the multiplex messages encoded by chaotic behaviors can be achieved. The disclosure of the present invention can be applied to many kinds of secure communication systems.

Discussion of the Prior Art

The technique of multiplex transmission has been well established in the field of conventional laser communications. However, it still lacks effective scheme of combining such laser multiplexing to chaotic secure communication systems. On the other hands, although it has been addressed that chaotic systems can be applied to secure communications, however, the conventional techniques of simplex-coupled synchronization can only work well in simplex transmission, it appeared some difficulties in handling multiplex transmission. The main reason can be attributed to the nonlinear interaction among the multiplex laser signals, resulting in a superimposed, interfered and complex chaotic system. To resolve these tow problems, a low-pass filter is utilized to increase the fractal dimension of the multiplex chaotic signals, so that the periodicity of these chaotic signals will be enhanced. This technique can be used to rebuild the multiplexed messages encoded by chaotic behaviors in laser communications.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method for handling laser-communication multiplexing in chaotic secure communications. By using a low-pass filter, a chaotic time sequence of lower fractal dimension can be effectively increased to a chaotic time sequence of higher fractal dimensional, so that the periodicity of the multiplex signals will be enhanced and hence the decoding of messages from the chaotic laser signals become possible.

It is another object of the present invention to provide a method for handling laser-communication multiplexing in chaotic secure communications, wherein the scheme of chaotic secure communications utilizes the behavior of extremely sensitive dependence on initial conditions and the feature of randomness of the chaotic laser light.

It is another object of the present invention to provide a method for handling laser-communication multiplexing in chaotic secure communications, wherein the scheme of chaotic secure communications is achieved by adjusting the coupling parameters of the receiver system, so that the chaotic system of the receiver end is simplex coupled to the transmitter end, and thus prohibiting the transmitted messages to be rebuilt by any unauthorized receptor.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram for describing a chaotic sequence generated from a self-pulsating laser diode by adjusting the amplitude and frequency of the externally applied driven ac current;

FIG. 2 is a block diagram for illustrating the procedure of synchronizing the chaotic laser signal of the receiver with that of the transmitter;

FIG. 3 is a block diagram for illustrating the use of low-pass filter to decode multiplexed messages encoded by chaotic signals;

FIG. 4(a) and (b) are the time sequence, Signal(t), of the multiplexed signals and the frequency spectrum of the multiplexed signal obtained by taking FFT to the Signal(t);

FIG. 5(a) and (b) illustrate the output, $e(t)$, of the receiver system after chaotic synchronization and the corresponding frequency spectrum after taking FFT to the $e(t)$;

FIG. 6(a) and (b) show the output, $y(t)$, from the low-pass filter of the present invention and the corresponding frequency spectrum after taking FFT to the $y(t)$; and

FIG. 7 is a flowchart for illustrating the scheme of the chaotic secure communication and a comparison between the procedures of the conventional system without using the low-pass filter of the present invention and the system of the present invention with the use of low-pass filter.

DETAILED DESCRIPTION

As has been approved by computer experiments and numerical simulations, the system and the method of the present invention is an effective scheme for handling the laser-communication multiplexing in chaotic secure communications, in which the system and the method for encoding and decoding the messages to be multiplexed comprise the following procedures,

1. Proceeding of chaotic behavior of self-pulsating laser diodes.

As shown in FIG. 1, the self-pulsating laser diode 12 is driven by an externally applied ac current, $I = a + b\sin(2\pi ft)$, where *a*, *b* and *f* are the offset current, the amplitude and the frequency of the ac current respectively. By adjusting the amplitude and the frequency of the input ac current, the self-pulsating laser diode will generate a chaotic laser light 13. The reason for this chaotic behavior is the conflict between the frequency of the applied ac current and the natural frequency of the self-pulsating laser diode 12, leading the system to a quasi-period-two behavior. According to the theory of chaos, i.e., quasi-period-two routes chaos, the self-pulsating laser diode 12 will generate chaotic laser signals 13 when the amplitude and frequency of the applied ac current are adjusted appropriately. The chaotic behavior of the laser output can be further

confirmed by Poincaré section, Lyapunov exponent and bifurcation diagram. This chaotic behavior is the most important precondition for encoding the message. Since a chaotic system depends sensitively on initial conditions and exhibits a random behavior, it is very difficult to decode the hidden message in the chaotic carrier.

2. Synchronization of the simplex-coupled chaotic proceeding.

Synchronization is the most important technique in communication applications. As shown in FIG. 2, the drive chaotic laser signals, which is detected by photo detector PD(D), and generated by the method described in step 1, from the transmitter end can be simplex-coupled to the response chaotic laser signals PD(R) of the receiver end by arranging same coupling coefficients between transmitter and receiver end. According to our computer experiments and numerical simulations, for a suitable coupling coefficient, the chaotic sequences of the response and the drive systems will be synchronized. This phenomenon is also the basic principle for utilizing these chaotic behaviors to the applications of secure communications. This synchronization can be further confirmed by using the conditional Lyapunov exponent. The signature of simplex-coupled behavior exhibited between two chaotic systems will prohibit the transmitted messages being rebuilt by any unauthorized receptor.

3. Proceeding of using simplex asymptotical synchronization principle.

Asymptotical synchronization is the most important technique for recovering the messages encoded by chaotic carrier. By using the simplex asymptotical synchronization principle, when the chaotic laser light of the transmitter containing messages is delivered to the receiver end, the receiver can reproduce a asymptotical synchronized chaotic laser light. The carried messages can then be rebuilt by taking fast-Fourier transformation (FFT) to the difference between the output signals of the transmitter and the receiver. This technique is well established for decoding a simplex transmission message. However, for the case of multiplex transmission, due to the complex phenomenon induced by the nonlinear interactions between different multiplex channels, it will appear some difficulties to rebuild the transmitted messages by simply taking FFT to the

synchronized chaotic systems. This can be seen in FIGs. 4(a), 4(b), 5(a) and 5(b). The messages to be multiplexed are shown in FIG. 4(a) and 4(b), which are the time sequences, $Signal(t)$, of the messages to be multiplexed and the corresponding frequency spectrum by taking FFT to the $Signal(t)$, respectively. The difference, $e(t)$, between the output signals of the transmitter and the receiver after synchronization is displayed in FIG. 5(a). However, as shown in FIG. 5(b), the transmitted messages cannot be rebuilt by simply taking FFT to the $e(t)$. Therefore, the decoding of multiplexed messages carried by chaotic signals should further utilize the technique described in the following procedure.

4. The use of low-pass filter proceeding.

This procedure is the most important technique for recovering the multiplexed messages encoded by chaotic signals, which is also the major part of the present invention. As shown in FIG. 3, due to the nonlinear interactions among different multiplex channels, the multiplex signals will interfere and superimpose with each other. Thus, the multiplexed messages cannot be fully recovered, if the conventional method as described in step 3 was used to decode them. To resolve this problem, this invention introduces a low-pass filter 21 to process the chaotic signals after synchronization. As illustrated in FIG. 7, first, the difference, $e(t)$, between the output of the transmitter and the receiver is sent into the low-pass filter. The low-pass filter can be described by the following differential equation,

$$\frac{dy(t)}{dt} = -\alpha y(t) + e(t)$$

where α is the parameter of the low-pass filter and $y(t)$ is the signal after low-pass-filtering. According our numerical simulations, if the parameter α is in the range of 0.13-0.97, the original chaotic time sequence of lower fractal dimensional will be transferred to a chaotic time sequence of higher fractal dimension. Owing to the higher fractal dimension, the periodicity of these multiplex messages will be emerged and hence the decoding of these

multiplexed messages can be achieved. The effects of the low-pass filter can be seen in FIG. 6(a) and (b). By comparing FIG. 6(b) with FIG. 4(b), it is clear that the multiplexed messages have been rebuilt by taking FFT to the signals after being sent through the low-pass filter of the present invention.